

The Evolution of Cluster Early-Type Galaxies Since $z=1$

Alexander Fritz (Gemini)

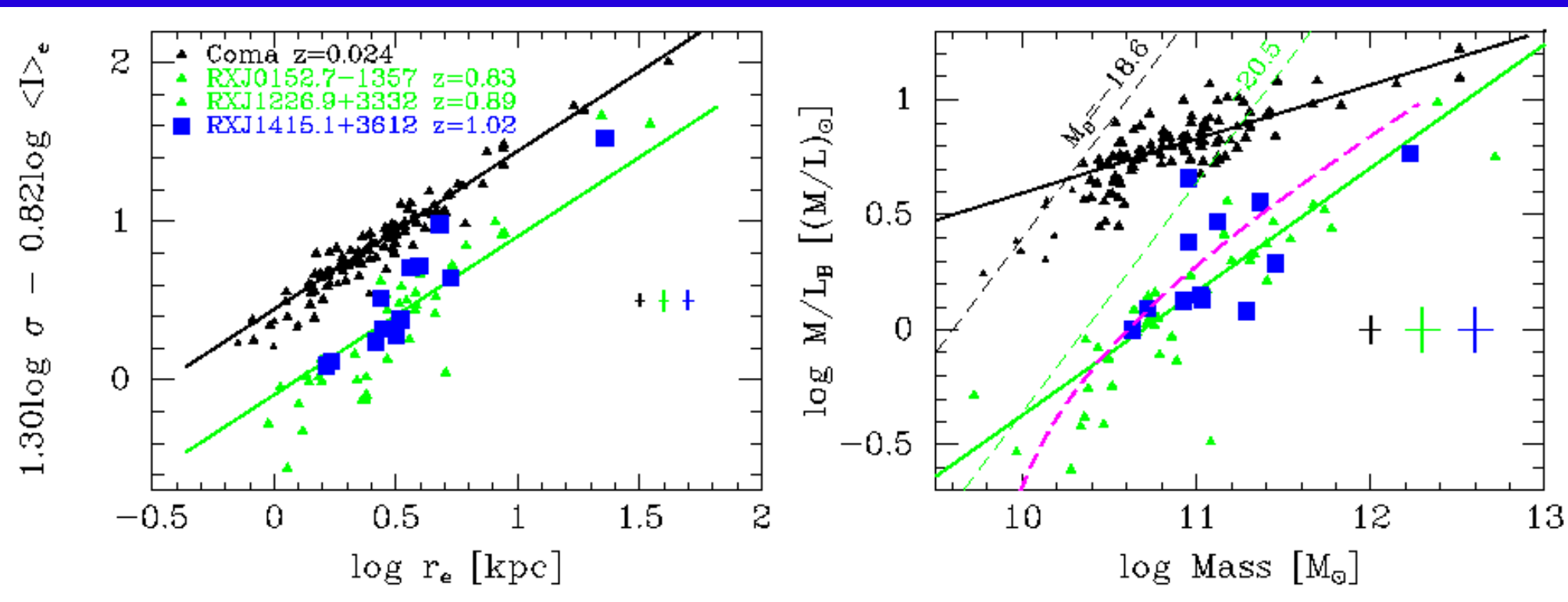
Inger Jørgensen (Gemini),

Ricardo P. Schiavon (Gemini), Marcel Bergmann (Gemini)

Roger L. Davies (Oxford), Jordi Barr (Oxford),

Kristin Chiboucas (IfA Hawaii), Kathleen Flint (NPA)

Main Result



Jorgensen et al. (2006), ApJ, 639, L9 + 654, L179

- First *detailed* Fundamental Plane of cluster E+S0 galaxies at $z=1$
- FP for $z=0.8-1.0$ has different slope than $z=0$ FP
- Mass-dependent evolution \Rightarrow Down-sizing

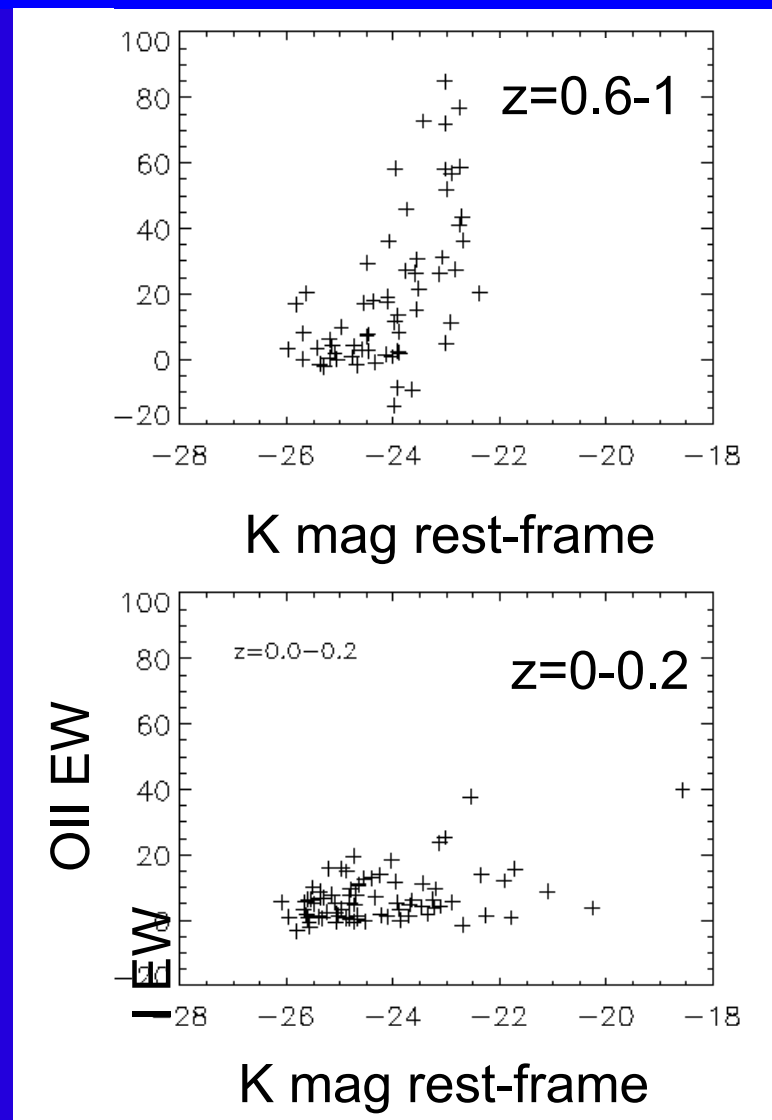
Down-sizing – independent results

Population of massive systems at $1 < z < 2$

Glazebrook et al. (2004), Bundy et al. (2006), Conselice et al. (2007)

Mass-dependent evolution for E+S0 galaxies

Kodama et al. (2004), Treu et al. (2005), Fritz et al. (2005)



Cowie et al. (1996)

Gemini/HST Galaxy Cluster Project

• Main Objectives

- Star formation history as function of redshift
- Evolution of morphologies \leftrightarrow Evolution of stellar populations/chemistry
- Variations in IMF? Substructure of clusters?

• Overview

- PI: Inger Jørgensen (Gemini)
Co-Is: Alexander Fritz (Gemini), Ricardo Schiavon (Gemini), Marcel Bergmann (Gemini), Jordi Barr (Oxford), Roger Davies (Oxford), Kristin Chiboucas (IfA), Kathleen Flint (NPA)
- 15 Rich Galaxy Clusters $0.1 < z < 1.0$, $L_X(0.1-2.4 \text{ keV}) \geq 2 \times 10^{44} \text{ ergs s}^{-1}$
- HST/ACS+WFPC2 + High S/N GMOS Spectra ($S/N \geq 25$ per \AA in rest-frame)
- Local Comparison Sample $z \approx 0.02$: Coma & Perseus

• Results

- Jørgensen et al. (2005), AJ, 129, 1249: Stellar populations in RXJ0152.7-1357 $z=0.8$
- Jørgensen et al. (2006), ApJ, 639, L9 + 654, L179: FP of cluster galaxies $z=0.8-0.9$
- Barr et al. (2005), AJ, 130, 445 +ApJ, 649, L1: SP+FP of RXJ0142.0+2131 $z=0.3$

GMOS *riz*-composite RXJ1415.1+3612



1 Mpc

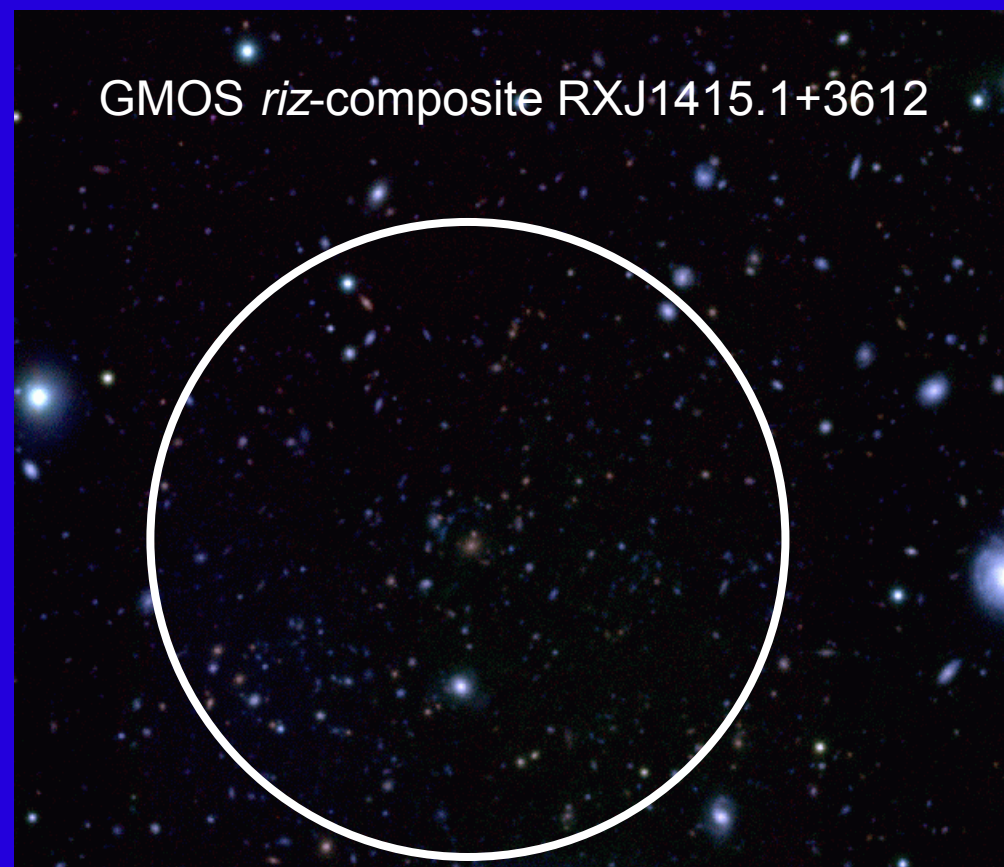
Cosmology:

$\Omega_{\Lambda}=0.7$, $\Omega_m=0.3$,

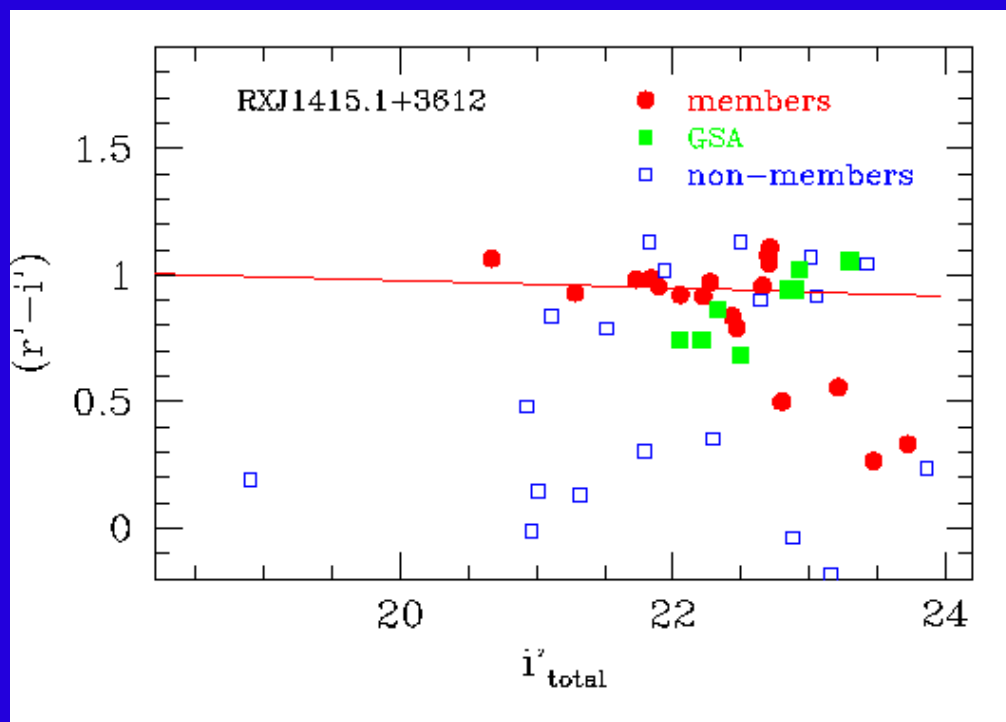
$H_0=70 \text{ km s}^{-1} \text{ Mpc}^{-1}$

Overview and Data

- GMOS high S/N spectra
S/N ~ 20 per Å in rest-frame
- HST/ACS: size & surface brightness
- $N_{\text{Spectra}} = 37$
- $N_{\text{Members, ACS}} = 14$



1 Mpc

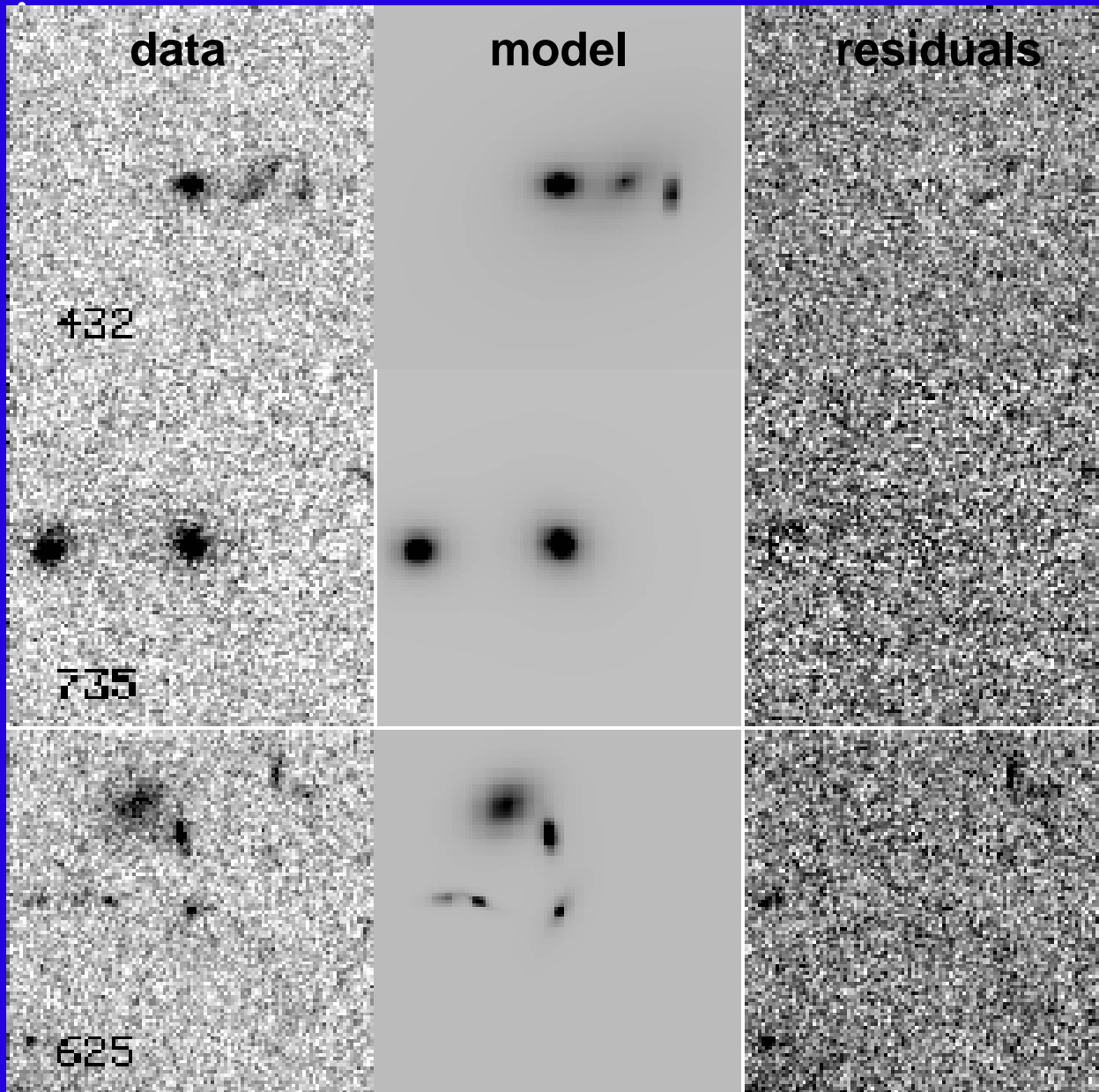


Red: Cluster Members

Green: Archive Data

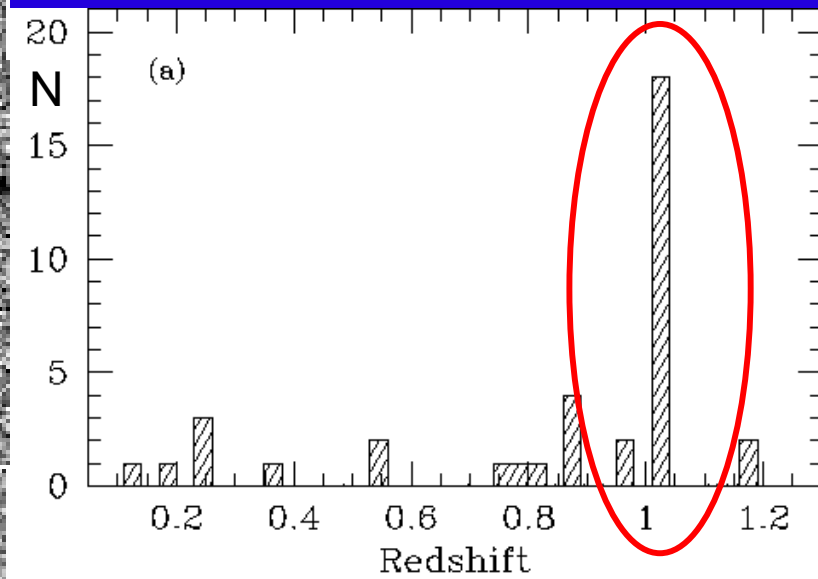
Blue: Field Galaxies

ACS Surface Photometry

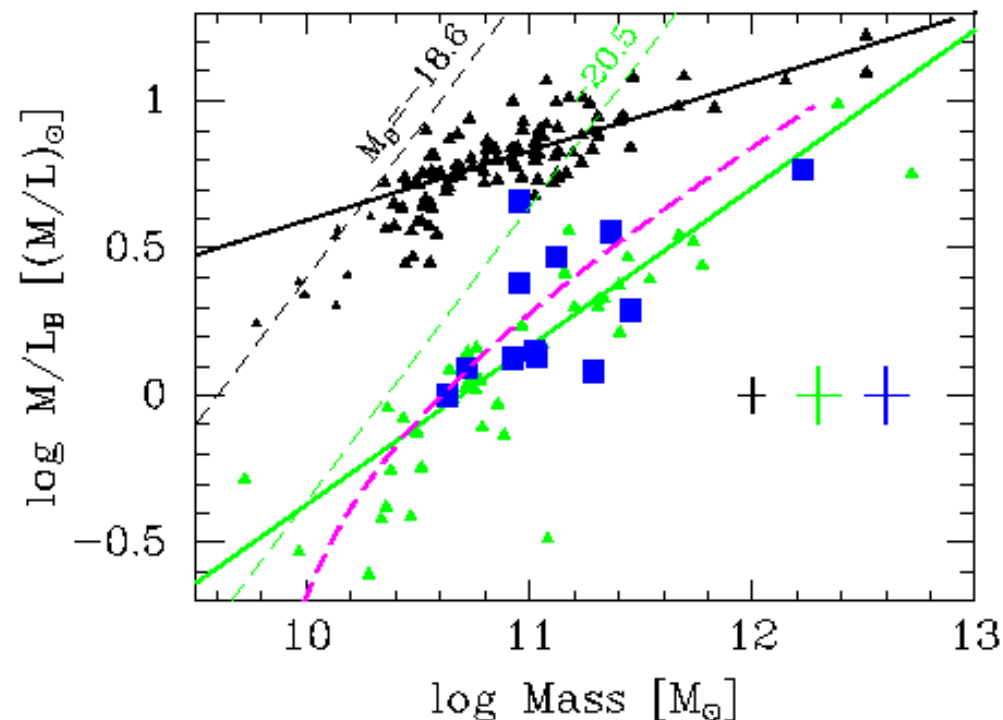
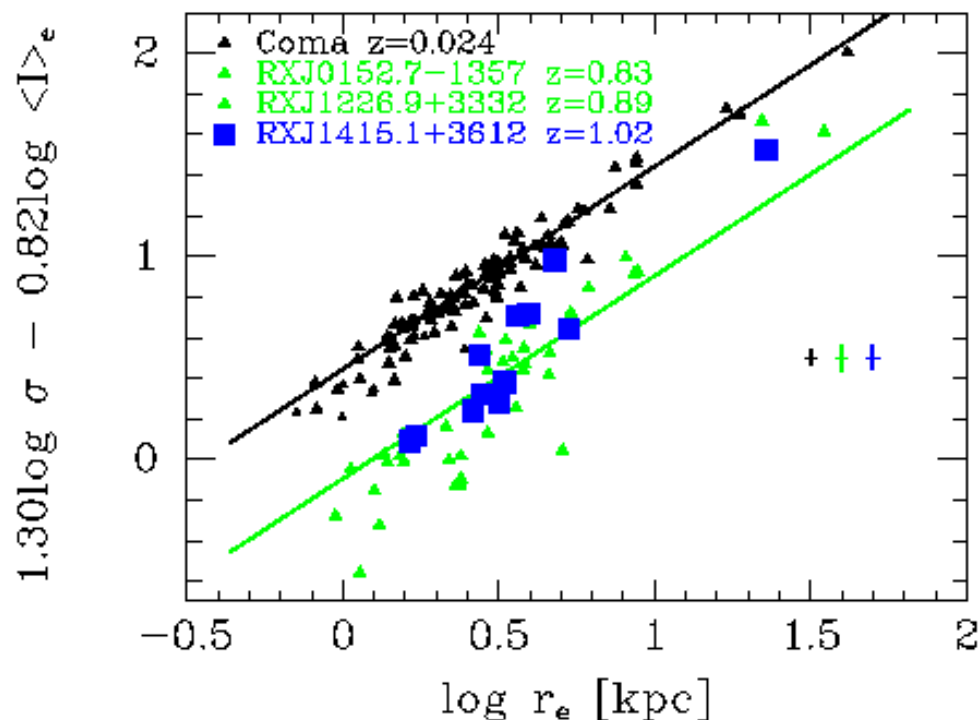


Redshift distribution:

$$z_{\text{Cluster}} = 1.025$$



Cluster E+S0 FP at z=1



Distant FP has steeper slope

Mass-dependent evolution

Lower-Mass $M^* \sim 3 \times 10^{10} M_{\text{sun}}$: $z_f \sim 1.1$

Higher-Mass $M^* > 2 \times 10^{11} M_{\text{sun}}$: $z_f \geq 4.5$

Jorgensen et al. (2006), ApJ, 639, L9 + 654, L179

Coma : $\log(M/L) = 0.24 \log M - 1.75$

$z=0.8-1$: $\log(M/L) = 0.54 \log M - 5.74$

\Rightarrow Down-sizing

Cowie et al. (1996), Kodama et al. (2004)

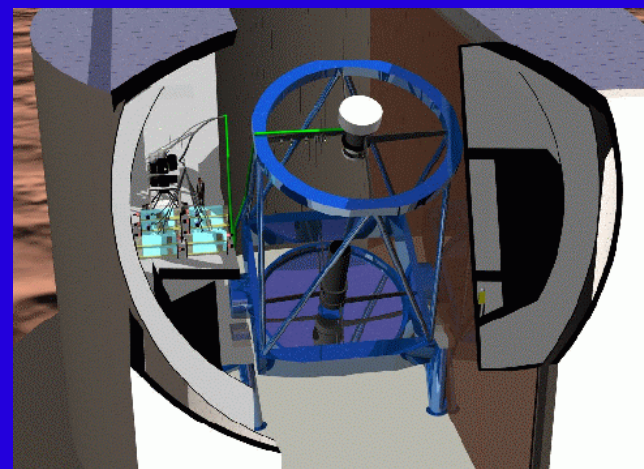
Consistent with SSP models: $t_f < 11$ Gyr (Thomas et al. 2005)

Does the FP for low mass galaxies exist at $z > 1$?

– a WFMOS project

• Why?

- FP at $z=1$ supports last major star formation episode for low mass galaxies at $z \sim 1.1-1.4$
- Lower mass systems most important to constrain models of galaxy formation



• How?

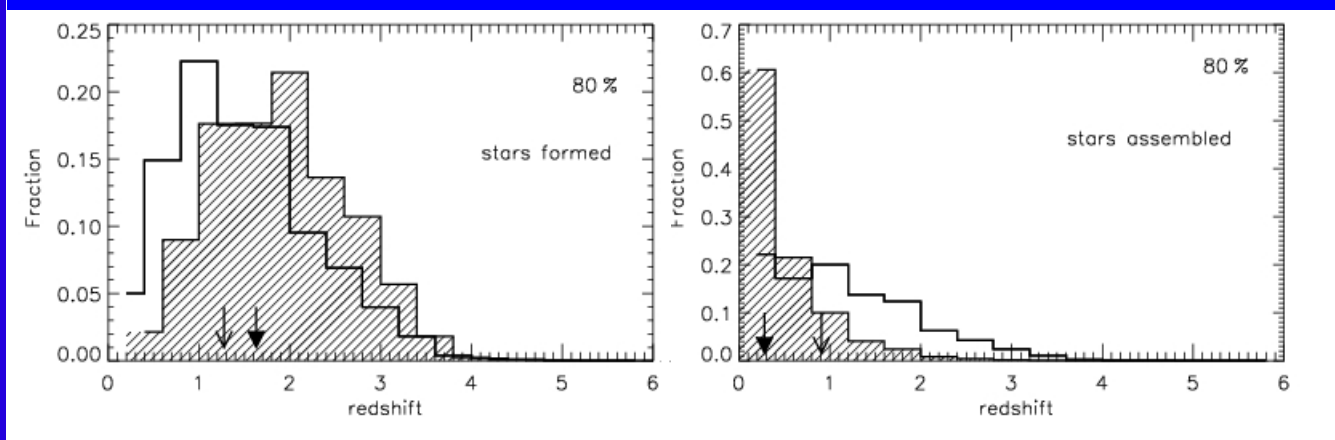
- Ultra-deep spectroscopy of lower-mass galaxies at $z \sim 1.3$
- Huge number of galaxies
- Stellar populations in the blue rest-frame 3400-4000 Å
- WFMOS on Subaru:

$z \sim 1.3$, $I \sim 23.0$ mag, $S/N \sim 15$ per Å in rest-frame \Rightarrow
 \Rightarrow requires 35 hrs total exposure time



END

Background



Mass assembly of massive E+S0s at $z < 1$ via mergers

Bower et al. (2006), de Lucia et al. (2006)

Population of massive systems at $1 < z < 2$

Glazebrook et al. (2004), Bundy et al. (2006), Cimatti et al. (2006), Conselice et al. (2007)

Continuous assembly of galaxies on the red sequence

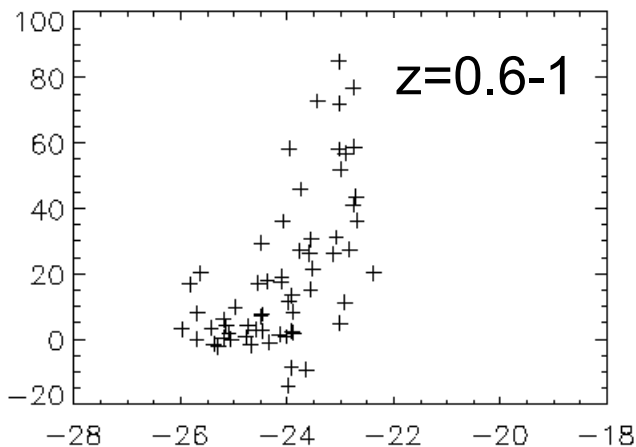
Bell et al. (2004, 2006), Faber et al. (2007), McIntosh et al. (2007)

Mass-dependent evolution for Field Galaxies

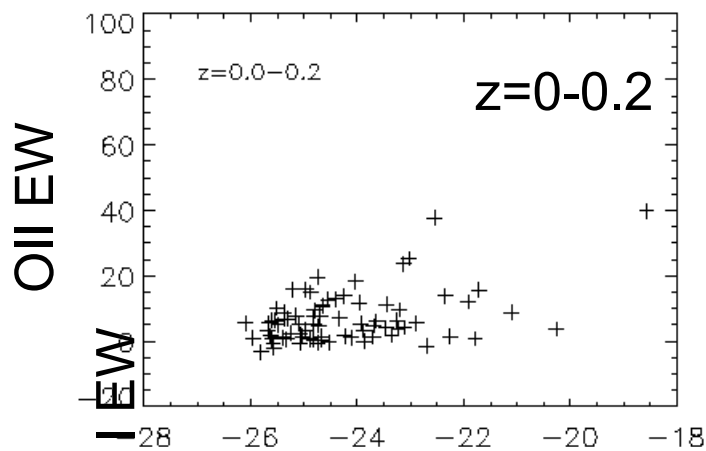
Early-type: van der Wel et al. (2005), Treu et al. (2005), Fritz et al. (2008)

Late-type : Böhm et al. (2004), (2007) Conselice et al. (2005), Kassin et al. (2007)

Downsizing – independent results

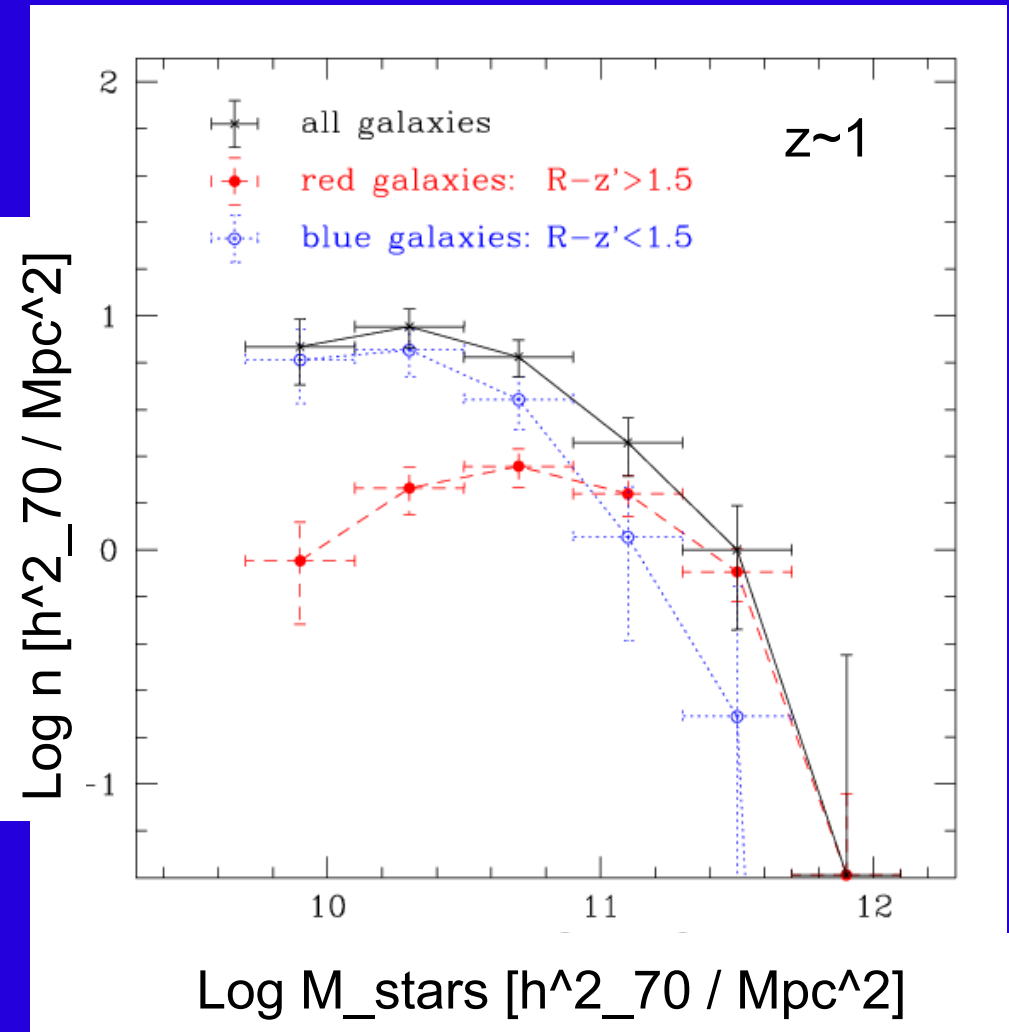


K mag rest-frame



K mag rest-frame

Cowie et al. (1996)

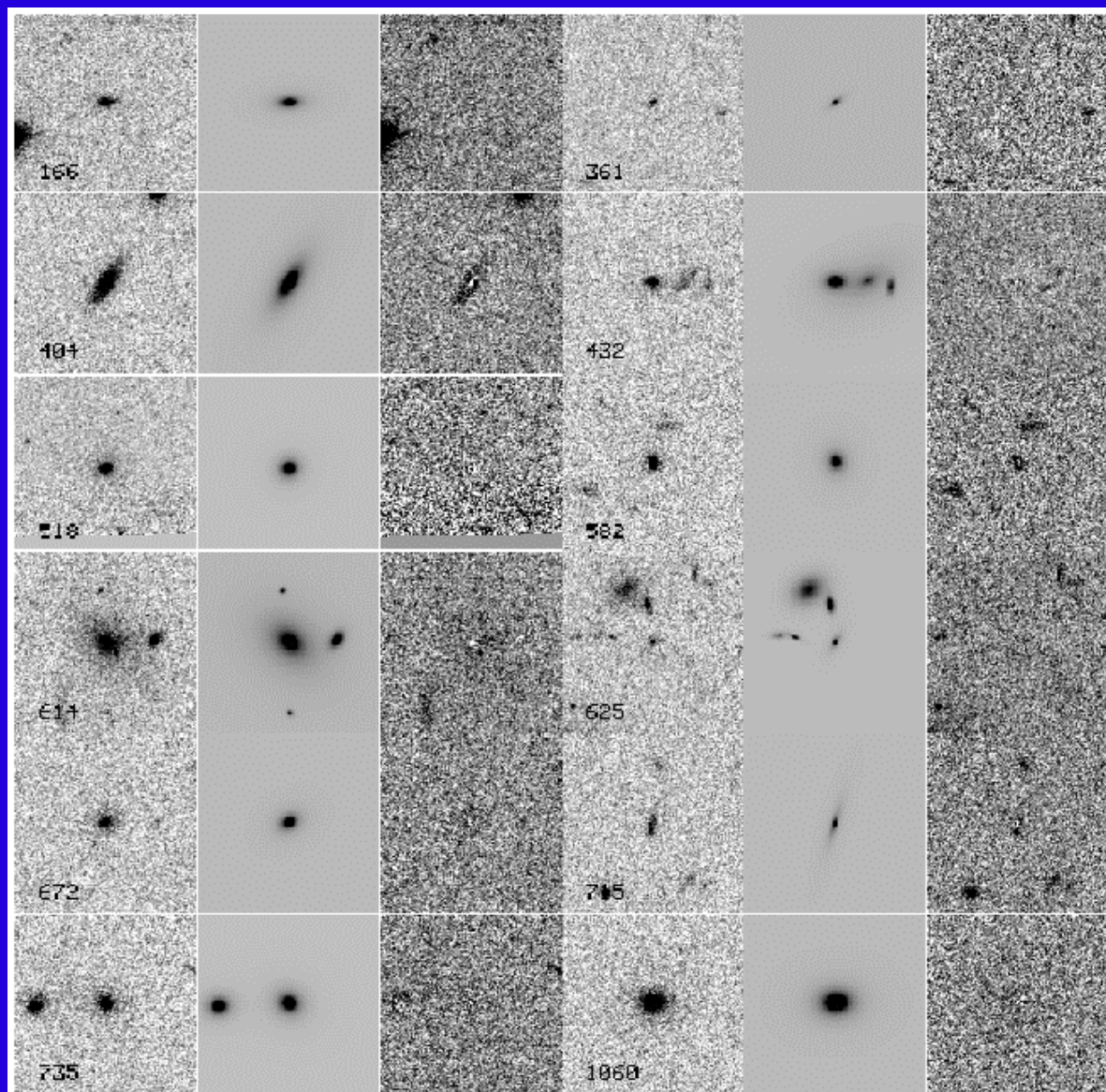


Kodama et al. (2004)

Population of massive systems at $1 < z < 2$ Glazebrook et al. (2004), Bundy et al. (2006)

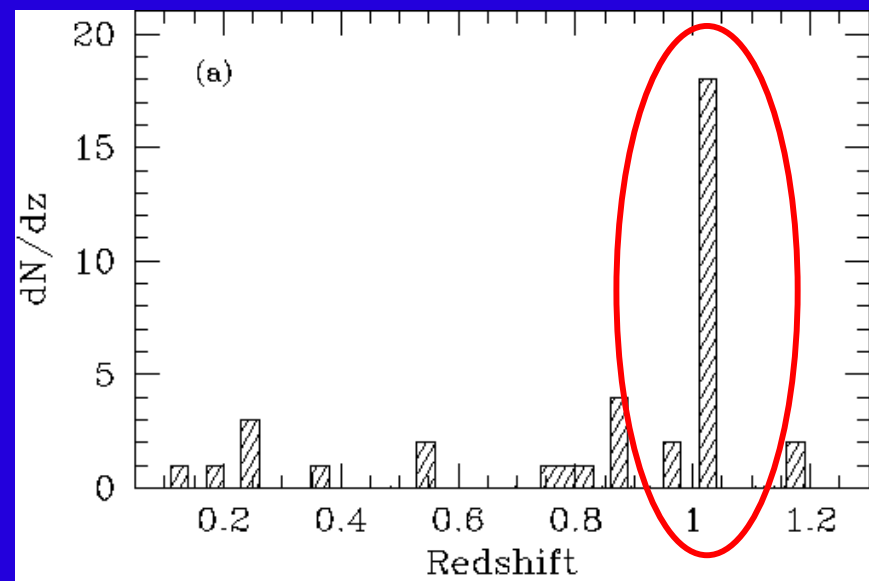
Mass-dependent evolution for E+S0 galaxies Kodama et al. (2004), Treu et al. (2005)

ACS Surface Photometry

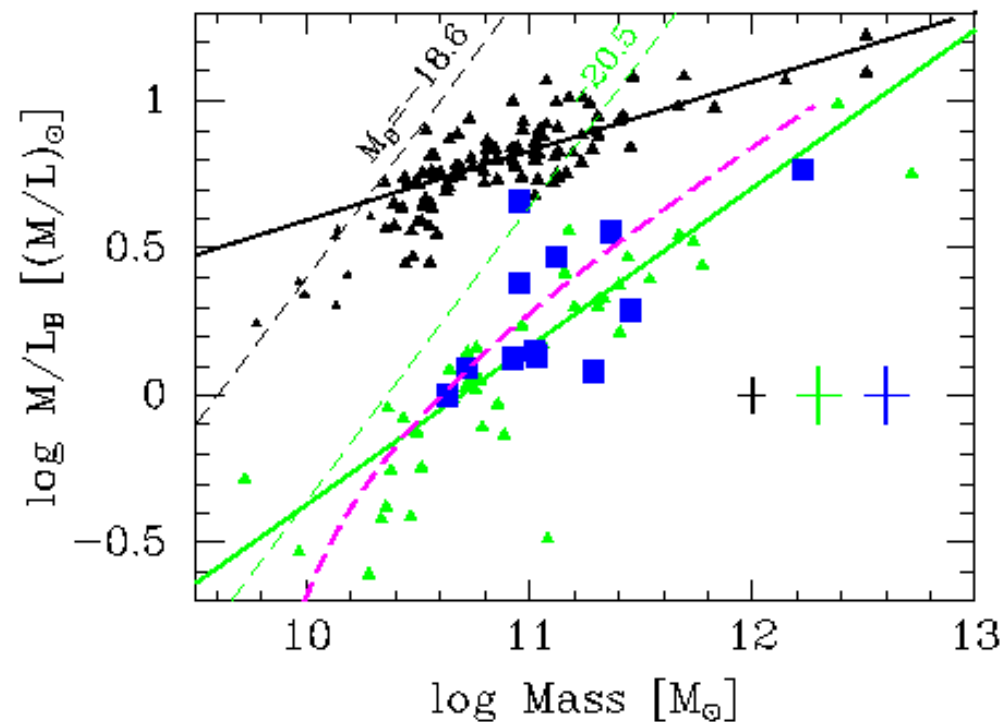
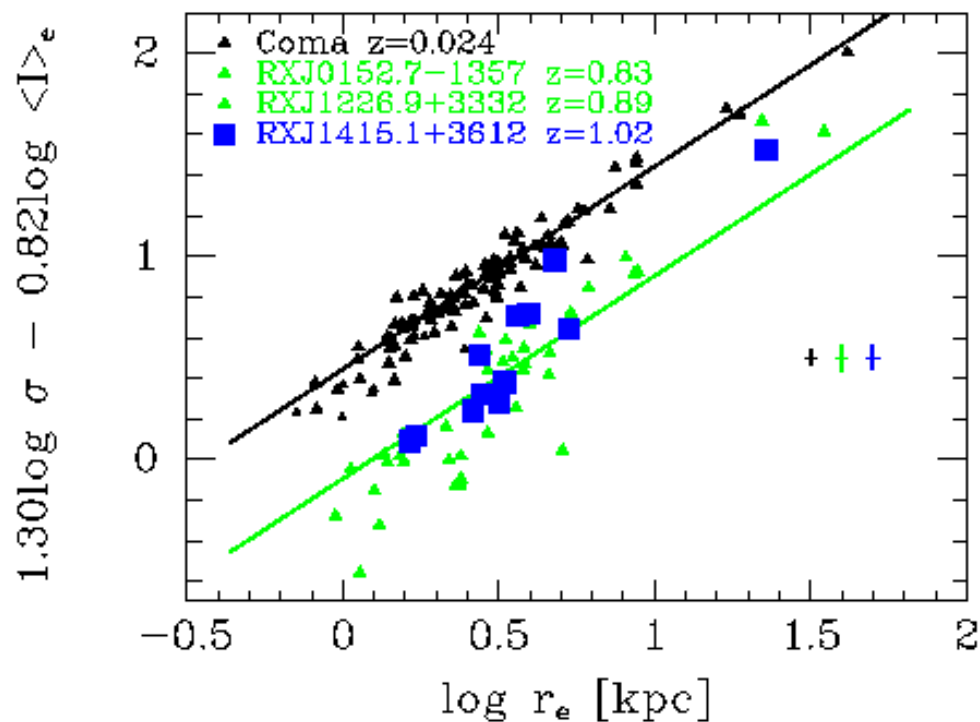


Redshift distribution:

$$z_{\text{Cluster}} = 1.025$$



Cluster E+S0 FP at z=1



Jorgensen et al. (2006), ApJ, 639, L9 + 654, L179

FP Coma : $\log(r_e) = 1.30 \log \sigma - 0.82 \log \langle I \rangle_e - 0.443$
 $z=0.8-1$: $\log(r_e) = 0.60 \log \sigma - 0.70 \log \langle I \rangle_e + 1.32$

M/L vs. M Coma : $\log(M/L) = 0.24 \log M - 1.75$
 $z=0.8-1$: $\log(M/L) = 0.54 \log M - 5.74$



END